An Exploration of Gene Therapy and Some Ethical Concerns: What Our Society Knows About Gene Therapy

An HonorsThesis (HONRS 499)

by

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Purpose of Thesis

The purpose of this thesis is to explore the issue of gene therapy. Background information is given to explain what gene therapy is and some of the ways it is accomplished. A discussion of organizations which regulate gene therapy is given. Also, some of the ethical issues that arise due to gene therapy are introduced. A determination of public knowledge is attempted by the use of a survey which was distributed to students and professionals. Statistical analyses are computed using the survey data to determine whether any correlation exist between certain groups of subjects and their responses to some of the survey questions. Finally, the thesis contains a section devoted to suggestions for further study.

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Introduction

One of the fastest growing fields of Biology is Genetics. Genetics is the study of heredity (5). However, the mechanism of inheritance took many years to work out. Individuals such as Mendel, Sutton, Morgan, Miescher, Watson, and Crick came across many discoveries which were instrumental in solving the puzzle of inheritance (14). Not only were the discoveries made by these people important in their own right, but they laid a basis that would assist in future genetic discoveries and techniques.

The field of Genetics studies the passing on of traits from one generation to another; a concept known as heredity (5). People are susceptible to inheriting deleterious traits as well as beneficial or normal traits. In some cases these bad traits may not be extremely harmful to the individual, such as in Marfan's syndrome (14). However, some inherited mutations may be deadly, such as in the case of Tay-Sachs disease (14). Using techniques such as genetic screening and gene mapping makes it possible to learn more about these unwanted genes and how to treat them (5).

This paper will focus on gene therapy, ethical problems that arise due to gene therapy, and the public's knowledge of gene therapy. Gene therapy is used to correct sequences of DNA in somatic cells or in the germ cells of an individual (12). The goal of gene therapy is to introduce normal genes into cells where abnormal genes have caused a disease(s) (5). However, before gene therapy is discussed the biological and genetic basis of inheritance will be presented.

Background Information

The human body is made up of approximately fifty trillion cells. These cells must contain information that allows them to function normally. If there was no such mechanism, cells would not be able to divide and make new cells. Fortunately, cells do possess this essential information in the form of genes, which are portions of DNA molecules (14). When the cells divide, DNA has been replicated and identical copies are passed on to the two daughter cells of each parental cell (14). This process, know as mitosis, ensures that each new cell contains all of the genes that were present in its parental cell (14). Each cell contains somewhere around one hundred thousand known genes (12).

There are two types of cells in the human body which contain these genes. The first type are somatic cells. Somatic cells are found in the skin, intestine, blood-forming tissues, and most other tissues of the body (14). All of these cells divide by the process of mitosis (14). They are not involved in fertilization and have no influence over an individual's offspring. The second type of cells are the germ-line cells, or sex cells. These cells include egg cells in females and sperm cells in males (14). Germ cells divide by meiosis, a process which results in cells which have only one copy of each gene (14). Germ cells are involved in sexual reproduction. Therefore, these sex cells can be considered the vehicles that transfer the parent's genes to the offspring.

Prospective parents hope for a healthy and happy baby. Unfortunately, this is not always the case. Often a gene that is inherited from one, or both parents, may be a

mutated gene. The mutation may not lead to any serious problems or it may cause a severe genetic disease. A parent that expresses a deleterious trait that is heritable may pass that gene on to his or her offspring. However, there are techniques such as gene therapy that may prevent a harmful gene from being passed on to an offspring (12).

Gene Therapy Techniques

Gene therapy is a relatively new genetic technique used to eliminate or prevent the inheritance of deleterious genes (12). Gene therapy can be used to correct genes in somatic cells and germ cells (12). It is not just one simple procedure. There are numerous ways in which it can be done. Nontargeted delivery of genes can be accomplished by viruses or by chemical or physical means (13).

Gene insertion is a procedure in which a new version of a gene is introduced into a cell (13). A common method of gene insertion employs the use of viruses. Viruses love to invade foreign cells and stick their own genes into the host's genetic material, thereby putting the virus in control (5). A virus is first crippled and rendered harmless (13). Then, the virus is altered so that it can carry genes into a target cell but not infect other cells (13). The term vector is often used to describe a virus treated in this way. The gene which is to be treated is removed from the patient's cell and altered with the correct sequence (13). Once this has been completed, the treated gene is inserted into the virus (13). The individual is then infected with the carrier virus so that the treated gene can be inserted into the cells of the individual (13). The newly inserted gene assumes the function

of the patient's own defective gene (5). Other kinds of viruses that travel to specific parts of the body are also being explored as vehicles to deliver desired genes (3).

Chemical methods involve the mixing of many copies of DNA carrying the healthy gene with a charged substance (13). Some examples of a charged substances are calcium phosphate, DEAE-dextran, and various lipids (13). Once this mixture is created it is dumped into recipient cells (13). The chemicals in the mixture disrupt the cell membrane and transport the DNA into the interior (13). This method is rather ineffective however. Only about 1 cell in 1,000 to 100,000 integrates the healthy gene (13).

A physical method of gene insertion is microinjection. A fine glass pipette and electroporation (exposing cells to an electric shock) are involved (13). The electric shock renders the cells permeable to the DNA in the surrounding medium from the injection (13). The DNA can then be incorporated into the cells. This procedure is more efficient than the chemical method. Nearly 1 cell in 5 may take up the foreign gene (13).

Types of Gene Therapy

There are two types of gene therapy. One type focuses on the somatic cells of an individual (12). Somatic cell interventions can be viewed as standard, medical interventions that repair damaged structures (11). The second type is germ-line gene therapy (12). This type of therapy is directed at the egg or sperm (12). It may also be done during the very early stages of development after fertilization (12). More specifically, this type of therapy is only practical if it is attempted within hours of fertilization (12).

Somatic cell gene therapy has many advantages over sex cell therapy. One such advantage is that the therapy can be performed during any stage of development of the individual (12). A second advantage relates to gene therapy experiments on somatic cells. Experiments on somatic cells may be done on samples or parts of organs, rather than the entire organ (12). This lowers the risks of failure because a failed experiment does not cause the loss of an entire organ (12). Also, somatic cell experiments can be repeated numerous times on the same individual (12). A final advantage of somatic cell gene therapy is that it is beneficial directly to the person receiving the treatment and does not become a part of the gene pool (12).

Unfortunately, there are some disadvantages to somatic cell gene therapy. One disadvantage is that diseases affecting more than one type of tissue may not be treated by somatic cell gene therapy (12). This is due to the fact that each cell or each tissue would have to be treated. Another disadvantage is that this type of therapy may not be effective on cells that do not divide (12). This would eliminate treatment of brain, nerve, and muscle cells.

Germ cell gene therapy has a an advantage. In germ cell therapy, once a defect has been corrected, that same defect much less likely to be inherited by an offspring (12). If the gene was corrected and inherited, then that offspring will now have a copy of the good gene in its genome to pass on to its own offspring. Theoretically, a deleterious trait could be eliminated from a population this way.

The disadvantages of sex cell gene therapy seem to greatly outnumber the advantages. Only a few will be mentioned in this paper. One disadvantage is that many

types of diseases are too complicated to treat (12). Some of these diseases may be inherited as autosomal dominant disorders, or they my be due to the interaction of multiple genes (12). Another disadvantage is that the responsible gene must have been located within the genome previously (12). If the location of a gene causing a genetic defect has not been found, then there is no way to treat it until it is located. Finally, germ-line gene therapy is a very controversial issue that has many ethical implications (11). The ethical aspects of a technique or procedure must be thoroughly examined before any action should take place.

Regulating Gene Therapy

Before research involving human subjects can be initiated, two types of committees are required to examine experiments and procedures. The Institutional Review Board (IRB) ensures that the research complies with the Department of Health Service's (DHHS) regulations (2). This is necessary for the protection of human subjects. The Institutional Biosafty Committee (IBC) must approve all research which involves gene insertion (2).

Several federal agencies are involved in regulating gene therapy. The National Institute of Health (NIH) approves research grants to do gene therapy research and ensures that federal research guidelines are followed (12). NIH is currently the most active agency involved in regulating gene therapy (12). The Recombinant DNA Advisory Committee (RAC) is a component of NIH. The RAC was established to develop guidelines for gene therapy research on human subjects (12).

Another federal agency involved in regulating gene therapy is the Food and Drug Administration (FDA). The FDA becomes involved in regulating gene therapy if products such as nucleic acids or genetically modified viruses are to be used (12).

The Ethics Advisory Board is made up of experts in the fields of ethics, law, medicine, and other experts on current topics (12). Its members are non-governmental individuals. This board is not a permanent agency, but is reconstituted when needed (12). The Ethics Advisory Board reviews questions and issues related to the progress of gene therapy (12).

"In 1980, at the urging of the major religious groups in this country, the President requested that the President's Commission for the Study of Ethical Problems in Medicine and Behavioral Research examine the topic of human genetic engineering" (2). Many other federally constructed committees are now exploring gene therapy. These committees include the following: The Human Gene Therapy Subcommittee, The Biotechnology Science Coordinating Committee, The Office of Technology Assessment, and The Biomedical Ethics Board (2).

Ethical Concerns Involving Gene Therapy

When considering gene therapy, many ethical issues arise. Whether or not gene therapy procedures ought to be done must be considered. A commentary entitled "Should scientists conduct experiments on the germ-line of humans?" shows two opposing views on that issue. David F. Koshland Jr. supports experimentation in the article but Stuart Newman is opposed to the experimentation (8). Often the ultimate consequences of new

research are not considered. This was exemplified in the film *Jurassic Park*. The scientists in the movie genetically engineered dinosaurs that escaped from their imprisonment and killed people. The rich entrepreneur was so overcome by what his scientists were capable of doing that he did not ask, should we be doing what we are doing? Fortunately, no one is genetically engineering dinosaurs in the real world, yet we do possess technologies that can be just as potentially dangerous. Before we decide whether to use a technology, we should consider the ethical implications it may have.

Ethical questions do not have a correct answer. "The decision-making process is further complicated by the observation that very few problems present genuine choices of unquestionable good over unquestionable evil" (7). If they did, we would not still be debating the issue of abortion. Someone may disagree with both extremes of an issue, yet agree with some aspects of one argument or both arguments. A suggestion to make an ethical decision may be to open-mindedly weigh as many aspects of the issue as possible before deciding.

This may be a hard task for one individual to complete. However, for a committee or group of individuals to make an ethical decision it may be an entirely different story. It seems that it would be extremely difficult to have all the members of a committee see eye-to-eye on ethical issues. Often, there may be members with totally opposed views that will never agree with one another.

There are many unsolved ethical issues involving gene therapy. Genetic manipulation of the germline could produce damage in future generations (1). This statement could arouse ethical debate. If we do not know the exact effect on future

generations should the procedure be done? Some people may feel that this is a risk worth taking while others may not.

Another question would be, do infants have the right to inherit a manipulated genome? (1). An issue such as this deals with the rights of the individual. However, how do we determine what rights the individual is allowed or is not allowed? Also, who should make a decision such as this? Maybe it should be the responsibility of geneticists. An ethics committee could be established to make the decision. There are numerous alternatives, but are any of these groups the correct choice?

There are also ethical dilemmas concerning informed consent. "...does the concept of informed consent have any validity for patients who do not exist..." (1). In other words, an unborn child cannot express informed consent about gene therapy. Does this mean that the procedure should not be done? That is an ethical question that may undergo considerable debate.

Another ethical question relates to the availability of treatment. If gene therapy can only be available to a few, and many are seeking it, how do we decide who receives it? The decision could be made by a doctor. It could also be left up to an ethics committee. "If the number of potential subjects exceeds the number of places available in the study, it may be very difficult to avoid making judgments about comparative social worth" (10). Factors such as the patient's age and the disease to be treated may limit the scope of this problem (10).

A final controversial issue is just how far should we go with gene therapy techniques and research? If we can alter genes to treat a disease, then maybe we can alter

them to produce a desired physical appearance. Is it possible that some day we will be able to have made-to-order babies? "...at what point do we cross the line into "playing God"?" (1). This is an important issue that could charge heated controversy. Do we have the right to manipulate our naturally inherited genes? If we do, how far do these rights extend? "The underlying concern among those who object most strenuously to the use of human gene therapy is that the new techniques eventually might be employed to alter genetic traits in normal individuals" (10). If gene therapy does reach this extent, can we consider it gene *therapy* any longer?

Gene Therapy and Public Knowledge

Unfortunately, many people are ignorant about gene therapy. This statement can be supported by the data obtained from the surveys which were distributed. In all research done for this thesis, a number or percentage of how many people did or did not know what gene therapy is could not be found. Some people have heard of it yet could not correctly say what it is if asked. Therefore, how can we make sound ethical decisions for people with limited knowledge? When decisions are being made for the general public, ought they know what it is that is being decided? A governmental official may announce to the public that gene therapy will only be available to medically related cases. People who do not know what gene therapy is will have no use for this information, whether they have a treatable disease or not.

To determine the public's knowledge about gene therapy a survey was created. The survey asked questions to determine how much people know or do not know about

gene therapy and what their opinions are concerning various issues. A copy of the survey can be found in the appendix of this paper.

The survey was given to students, geneticists, and other medical professionals. The first question of the survey was used to determine what grade level the subjects were in at present. At this point in the paper only student responses will be discussed. The subjects were members of all undergraduate grade levels: freshmen, sophomores, juniors, and seniors. The second question of the survey was used to determine the majors of the subjects. The students surveyed fell into a wide variety of majors (Tables 1 & 2).

Table 1. "Class Distribution"

Class Level	Percentages
Freshmen	38.6%
Sophomores	30.2%
Juniors	14.9%
Seniors	16.3%

Table 2 shows the distribution of the subjects majors.

Table 2. "Major Distribution"

Majors	Percentages
Social Science	11.4%
Science	12.9%
Communication	11.4%
Education	11.9%
Business	21.3%
Fine Arts	5.4%
Math and Computer Science	5.0%
Architecture	4.5%
Undecided	10.4%
Miscellaneous	5.9%

A sample such as this should produce people with none to much knowledge about the topic of gene therapy.

The next aspect of the survey dealt with the subjects' background knowledge in Biology and gene therapy. The question asked whether the students had taken specific biology classes or ethics classes. The classes placed in the survey were an introductory biology class (Bio 100), Genetics (Bio 2140, Cell Biology (Bio 215), Honors Biology (Bio 299), BioEthics (Bio 492), any ethics classes, or none. Table 3 summarizes the subjects' responses.

Table 3. "Background Information of Students"

Classes Taken	Number of Students
Bio. 100	84
Bio. 214	3
Bio. 215	3
Bio. 299	52
Bio. 492	1
Ethics	13
None	60

The majority of the two hundred and two subjects have had at least one of the classes in question. However, 29.85% of students no background in Biology or Ethics. Subjects with no background in these classes have probably never had formal college course work involving the topic of gene therapy. However, the subjects may have been exposed to the topic through television or personal reading.

The next question on the survey asks the subjects to indicate what gene therapy is. The data collected are displayed in Table 4.

Table 4. Responses to "What is Gene Therapy?"

Possible Responses	Number of Replies
The removal of unwanted DNA...	19
The cutting of DNA with endonucleases	13
Manipulating a person's gene in the attempt...	180
Inserting the DNA of one species...	5

There was a total of 217 responses to this question. However, the sample consisted of only 202 subjects. This indicates that some people replied with more than one answer. Response 3 gives the answer that shows the general purpose of gene therapy. The data indicate that even though the subjects may not have a strong background in fields relating to gene therapy, about three fourths or more of them understand the goal of gene therapy.

Table 5. "Which Diseases can be Treated by Gene Therapy?"

Diseases	Number of Responses
Huntington's Disease	78
Polycistic Kidney Disease	15
Familial Hypercholesterolemia	27
Phenylketonuria	48
Beta-zero-thalassemia	13
Adenosine Deaminase	29
Malignant Melanoma	18
AIDS	6
Lesh Nyhan Syndrome	18
None	54

Table 5 is a display of the responses to which diseases can be treated by gene therapy.

Table 6. "Do You Know the Difference Between Somatic Cell and Sex Cell Gene Therapy?"

Responses	Number of Replies
Yes	32
No	170

Since gene therapy can be done on both sex cells and somatic cells this question of the survey indicates that most subjects do not have an in-depth understanding of gene therapy. If the respondents do not know the difference between the types of therapy then they cannot know how gene therapy can effect each type of sex. Somatic cell therapy would affect only the individual receiving the therapy and sex cell therapy would affect the individual's offspring.

The next question dealt with ethical problems concerning gene therapy. The replies are summarized in the Table 7.

Table 7. "Ethical Problems with Gene Therapy"

Replies	Number of Responses
Some religious beliefs...	132
Gene therapy is too time consuming	26
Gene therapy costs too much	70
There are no laws involving...	75
There may be philosophical beliefs...	95

Over half of the subjects felt that religious beliefs may impede gene therapy. Also, approximately half of the respondents felt that philosophical beliefs may affect attitudes about gene therapy. Response 4 is incorrect. There are laws and regulations involving gene therapy. Many organizations exist that place strict rules upon gene therapy. However, 75 people did not know that they existed.

The next question asked the subjects whether they would have gene therapy done on themselves. Out of 202 responses, over 60% indicated they would have gene therapy done on themselves (Table 8).

Table 8. "Would You Have Gene Therapy Done on Yourself?"

Responses	Number of Replies
Yes	128
No	74

Subjects were then asked how gene therapy should be funded. The responses to this question were also somewhat interesting. The responses are displayed in Table 9.

Table 9. "How Should Gene Therapy Be Funded?"

Responses	Number of Replies
Health insurance	119
Governmental funding through taxes	41
The person seeking the therapy should fund it...	67
It should not be funded because...	11

Although most subjects indicated that gene therapy should be funded by health insurance, 41 subjects thought gene therapy should be funded through taxes. In a society

that is perceived to be in favor of lower taxes, many people still feel that is a good method of funding. Only 5.45% of the subjects were against gene therapy being done at all.

The final question dealt with regulating gene therapy. The subjects were asked what kinds of restrictions or regulations should we place on gene therapy. Their replies are found on Table 10.

Table 10. "What Kinds of Restrictions or Regulations Should We Place on Gene Therapy?"

Responses	Number of Replies
Gene therapy should only be available to people who can afford it	13
Gene therapy should only be allowed in medically related cases	153
Gene therapy should be available to anyone for any reason	31
Gene therapy should not be performed at all	12

The majority of subjects believed that gene therapy should be available only in medically related cases. This suggests that most people are concerned with treating disease to help people rather than producing children with specific characteristics. One more person has now responded that gene therapy should not be done at all. Twelve people responded with that answer, yet in the last question only eleven people replied with that answer.

In order to determine whether grade level had an influence on student knowledge of gene therapy, the question of whether the students knew the difference between somatic cell and sex cell gene therapy was examined. The null hypothesis was that there was no significant difference between the number of "yes" responses as the grade level

increased. The alternate hypothesis was that there is a significant difference in the number of "yes" responses as grade level increases. For all of the statistical tests, the response of "yes" was given a value of 1 and the response of "no" a value of 0.

The test chosen was a two sampled t-test with a pooled variance. The two sample test was appropriate because a comparison was being made between two populations rather than one population being compared to a known mean. In the second case a one sample test would have been the best to use.

The following equations were used to obtain the statistics:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

$$s_x^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}$$

$$t = \frac{\bar{x} - \bar{y}}{s_p \sqrt{\frac{1}{n} + \frac{1}{m}}}$$

with

$$S_p = \sqrt{\frac{(n-1)s_x^2 + (m-1)s_y^2}{n+m-2}},$$

where n is the number of elements of the x data range and m is the number of elements of the y data range (6). X bar, in the first equation, represents the sample mean (6). The

second equation is used to determine the sample variance (6). The next equation is used to calculate the t statistic (6). The final equation is used to compute the pooled variance which is used in the calculation of the t statistic (6).

Before the t-tests could be computed, the means and variances for all of the class levels were determined using the first two equations. It is also important to take into account the size of each sample which is being tested. For all of the t-tests the null hypothesis is not rejected if the tabled value falls below the .90 significance level. The results of these computations are summarized in the following table of values.

Table 11. "Individual class statistics"

Grade Level	n	$\bar{x}$	s_x^2
Freshman	79	0.063291	0.0600454
Sophomore	58	0.189655	0.156382
Junior	30	0.233333	0.1850575
Senior	34	0.235294	0.1853832

These results were used to compute the pooled variances and the t statistics. The pooled variance values, the t statistics, the significance levels at which the results would allow the null to be rejected, and whether the null is rejected or not are shown in Table 12.

Table 12. "Summary of t-test results"

Comparison	s_p	t	Significance Level	Reject Null or Fail to Reject Null Hypothesis
Fresh./Soph.	0.113945	-6.560348	0.995	Reject
Soph./Juniors	0.1666041	-1.1657632	0.75	Fail to reject
Juniors/Seniors	0.1852309	-0.0422644	0.6	Fail to reject
Fresh./Juniors	0.1091328	-7.2654385	0.995	Reject
Fresh./Seniors	0.1129192	-7.426428	0.995	Reject
Soph./Seniors	0.1675995	-1.2607325	0.75	Fail to reject

When analyzing the t-test results for this question it was found that the number of responses of "yes" for all of the grade levels was significantly greater than the number of "yes" responses made by the freshmen. These results indicate that most freshmen have probably not a class dealing with the types of gene therapy yet.

However, when examining the other test results there was not strong enough evidence to support the hypothesis that as grade level increases, so does knowledge of gene therapy. The comparisons of sophomores and juniors, juniors and seniors, and sophomores and seniors, having significance levels of <.75, <.90, and <.75 respectively, cause the null not to be rejected. Therefore, grade level does not seem to be correlated with the amount of knowledge the subjects have about the types of gene therapy.

A second set of t-tests involved the question of whether or not the subjects would have gene therapy done on themselves if they had a genetic disease. The null hypothesis was that there was no significant difference in the number of "yes" responses as grade level increased. The alternate hypothesis was, as grade level increased the number of "yes" responses would increase. Tables 13 & 14 summarize the results.

Table 13. "Individual class statistics"

Grade Level	n	$\bar{x}$	s_x^2
Freshman	79	0.56962	0.248296
Sophomore	58	0.687655	0.2177858
Junior	30	0.533333	0.2574713
Senior	34	0.676471	0.22549

Table 14. "Summary of t-tests"

Comparisons	s_p	t	Significance Level	Reject or Fail to Reject Null
Fresh./Soph.	0.2358957	-2.9427619	>.995	Reject
Soph./Juniors	0.2319282	2.9970903	<.60	Fail to Reject
Juniors/Seniors	0.2409779	-2.3713072	>.99	Reject
Fresh./Juniors	0.2508159	0.6746164	<.60	Fail to Reject
Fresh./Seniors	0.2417407	-2.1549768	>.975	Reject
Soph./Seniors	0.2206419	0.2766424	<.60	Fail to Reject

For these analyses there were only three situations in which the null hypothesis can be rejected. Those three cases are in comparisons of freshmen and sophomores, juniors and seniors, and freshmen and seniors. In this study sophomores were most willing to have gene therapy done if they had a genetic disease. These tests do not appear to show any correlation between grade level and likelihood to have gene therapy done.

The comparisons of the sophomores and juniors, freshmen and juniors, and sophomores and seniors, significant at levels all <.60, are not strong enough to conclude that the higher of the two grade levels has a significantly greater response of "yes". The junior class appeared to be the odd group in the study. Table 14 shows that the group of juniors were less willing to have gene therapy then the other classes. To sum things up,

there is no strong evidence to support the hypothesis that the higher grade level the more likely one is to have gene therapy if that person had a genetic disease.

Next, replies of science majors were compared with those of non-science majors concerning the same two questions. The first test dealt with whether the subjects knew the difference between somatic cell and sex cell gene therapy. The null hypothesis was the number of "yes" responses of science majors are not significantly greater than that of non-science majors. The alternate hypothesis was the number of "yes" responses of science majors is significantly greater than non-science majors. The statistical results are found in the following tables.

Table 15. "Individual major statistics"

Major	n	$\bar{x}$	s_x^2
Science	26	0.3076923	0.2215385
Non-science	175	0.1314286	0.1148112

Table 16. "Summary of t-tests"

Comparison	s_p^2	t	Significance Level	Reject or Fail to Reject Null
Sci./Non-sci.	0.1330089	-6.3050691	>.995	Reject

These results strongly support that there is a correlation between major and knowledge of gene therapy types. Science majors have a much greater understanding of the types of gene therapy than non-science majors according to Table 16.

The final test was used to determine whether science majors were more likely to have gene therapy if they had a genetic disease than non-science majors. The null

hypothesis was that the number of "yes" responses of science majors was no different or less than that of non-science majors. The alternate hypothesis was that the number of "yes" responses of science majors was greater than that of non-science majors. The data of these calculations is displayed in the next two tables.

Table 17. "Individual major statistics"

Major	n	$\bar{x}$	s_x^2
Science	26	0.6923077	0.2215385
Non-science	175	0.614286	0.2389491

Table 18. "Summary of t-tests"

Comparison	s_p	t	Significance Level	Reject or Fail to Reject Null
Sci./Non-sci.	0.2368321	-1.5674096	>.90	Reject

The >.90 significance level found for this test provided strong evidence that there is a correlation between major and willingness to have gene therapy for a genetic disease. It was determined that the science majors were more likely to agree to have gene therapy.

The same survey was distributed to a group of professionals. These professionals included geneticists and professors of Genetics. The results of those surveys are summarized in the following tables. The replies of the geneticists should be representative of an educated population on the topic of gene therapy. It is interesting to see the differences in the replies between the population of professionals and the population of students.

Table 19. "What is gene therapy?" Professionals' replies.

Responses	Number of Replies
The removal of unwanted DNA...	1
The cutting of DNA with endonucleases	1
Manipulating a person's genes in the attempt...	9
Inserting the DNA of one species...	1

All of the responses in Table 9 are aspects of gene therapy. However, response three is the correct answer. All of the professionals answered with response three. One professional replied with all of the choices which is also correct. These data corresponds well with the student responses. The majority of student responses were choice three as well.

The second question was "Which disease can be treated by gene therapy?". The professionals' responses are displayed in the following table.

Table 20. "Which disease can be treated by gene therapy?"

Type of Disease	Number of Responses
Huntigton's Disease	0
Polycistic Kidney Disease	0
Familial Hypercholesterolemia	1
Phenylketonuria	0
Beta-zero-thalassemia	0
Adenosine Deaminase	7
Malignant Melanoma	1
AIDS	1
Lesh Nyhan Syndrome	0
None	1

The responses to this question were very different than those of the students. The most common response among the students was Huntington's disease. That particular disease is not treatable by gene therapy at the present time. The professionals' responses involved only five choices: Familial Hypercholesterolemia, Adenosine Deaminase, Malignant Melanoma, AIDS, and none. In all of my research I found only choice, Adenosine Deaminase, to be treatable. However, experimental gene therapy procedures are being tried on nearly all of the other diseases according to many of the professionals' comments on the survey. A much higher percentage of professionals chose ADA than the students did. This indicates that the professionals are acquainted with current gene therapy treatments. However, the students appear to be lacking of that knowledge.

The next question also involved the subjects knowledge of gene therapy. The question was asked to determine if the professionals knew the difference between somatic cell gene therapy and sex cell gene therapy. Table 21 contains those results.

Table 21. "Do you know the difference between somatic cell and sex cell gene therapy?"

Responses	Number of Replies
Yes	7
No	2

The table shows that the majority of subjects knew the difference. Only 77.8% of the professionals knew what the difference was (Figure 13). The professionals proved to be much more knowledgeable than the students. Only 15.8% of the students knew the difference (Figure 6). This low percentage may be due to the students lack of experience in the fields of biology and genetics.

The next question deals with ethical problems that may arise due to gene therapy. The responses are summarized in the following table.

Table 22. "What are some ethical problems with gene therapy?

Responses	Number of Replies
Some religious beliefs...	5
Gene therapy is too time consuming	1
Gene therapy costs too much	4
There are no laws involving gene therapy	3
There may be philosophical beliefs against gene therapy	3
None	3

The response of "None" was also included since many professionals commented that on the surveys. Again, these results were similar to those of the students. The most frequent answer was response number one. Most subjects in both populations were concerned with the religious views about gene therapy. However, many of the professionals believed that the cost of gene therapy was the second most important concern. The students felt that philosophical views about gene therapy were the second most important aspect.

The survey then asked if the subjects would have gene therapy done to themselves if they a genetic disease. The responses are displayed in Table 15.

Table 23. "Would you have gene therapy done on yourself if you had a genetic disease?"

Responses	Number of Replies
Yes	9
No	0

Every one of the professionals agreed that they would have gene therapy if they had a genetic disease. In comparison to the student responses the professionals outnumbered them greatly in their response of "yes". Only 63.4% of the students replied that they would have gene therapy done (Table 8). This response is most likely do to lack of knowledge about gene therapy on the part of the students.

The next question dealt with the funding of gene therapy. The following table contains that data.

Table 24. "How do you think gene therapy should be funded?"

Responses	Number of Replies
Health insurance	9
Governmental funding through taxes	4
The person seeking the therapy should fund it...	1
It should not be funded because...	0

The professionals' responses were similar to those of the students. Both populations believed that health insurance was the best method of funding gene therapy (Tables 9, 24). There was a difference in the second most frequent choice. The professionals felt that funding through taxes was the next best way of funding. However, the students chose personal funding as their second choice. These data indicate that the subjects would rather be covered by health insurance than directly paying for gene therapy in the form of taxes or with personal funds.

The final question dealt with restrictions. The question was used to determine in which cases gene therapy should be available. Table 25 displays the professionals' responses.

Table 25. "What kinds of restrictions or regulations should we place on gene therapy?"

Responses	Number of Replies
Gene therapy should be available only to people who can afford it	0
Gene therapy should only be allowed in medically related cases	9
Gene therapy should be available to anyone for any reason	0
Gene therapy should not be performed at all	0

The professionals chose response two by 100% (Figure 17). The students also chose response two as their most frequent choice (Table 10). However, the students also chose the other responses. The professionals appeared to place a priority on health. The students also seemed to feel that the priority of gene therapy should be to treat diseases.

Conclusion

The purpose of this thesis was to determine public knowledge of gene therapy and opinions on ethical issues involving gene therapy. Background information on gene therapy was presented first to give an understanding of the uses of gene therapy. The advantages and disadvantages of the types of gene therapy, and some of the ethical issues that arise due to gene therapy were then discussed.

A survey was given to students and professionals to determine the knowledge the subjects had about gene therapy and what they feel are some of the ethical arguments that may arise from gene therapy.

One prediction was that the student population was not fully knowledgeable of what diseases could be treated by gene therapy. The students chose Huntington's disease more than any of the others as the disease that could be treated. Huntington's disease is an autosomal dominant disease that is a very unlikely candidate for treatment at this time. The professionals chose Adenosine deaminase more often than any other disease. This disease is the only one that has been documented to be treatable at the present time. Most of the others an being tested experimentally at this time.

Secondly, the student population was not acquainted with the types of gene therapy. Only 15.8% of the students knew the difference between somatic cell and sex cell gene therapy (Figure 6). However, with a sample size of 9, 77.8% of professionals knew the difference (Figure 13).

As for ethical concerns, occupation, grade level, or major do not appear to have a great effect on a person's beliefs. Tables 7, 10, 22, and 25 help to support this claim. On Tables 7 and 22, response 1 had the most replies. On Tables 10 and 25, choice 2 was answered most frequently. The student population and the professional population chose the same replies most frequently. Also, the student population was very diverse. Therefore, students from all majors and grade levels were all contributing to the most frequent responses.

One ethical question involved how gene therapy should be regulated. When the data for this question are examined, the majority of students and professionals believed that gene therapy should be allowed only in medically related cases (Tables 10, 25). Many people seem to be against the "abuse" of science. Gene therapy has the potential of being abused. Some of the strongest supporters of genetic research are the first to admit the potential for its abuse (15). By examining Tables 10 and 25, it appears that people may realize that gene therapy has the potential of being abused and that is why the majority of them feel it should be restricted to only medical uses.

It is very difficult to determine what an ethical decision should be based on. In the research done for this thesis no agreement could be found on a correct method to go about decision-making. However, some individuals seemed to mention that an individual's values were important. "Differences in ethics means that underlying value structures differ..." (4). This statement is an example that values affect a person's ethics. A second factor in ethical decision-making that was mentioned was that of education. "Certainly if society is to deal with the moral-ethical issues raised by the application of advances in medical genetics, a reasonable measure of genetic literacy is essential" (9). Therefore, it appears that a person should be genetically literate, or educated, to make an ethical decision about gene therapy. This statement can also be supported by the statistical tests done on science major versus non-science majors.

The statistical analyses which were performed showed some interesting results. It was hypothesized that grade level would have an effect on the subjects knowledge of gene therapy type. However, when the results were examined, this not found to be the case

(Table 12). There must be other factors influencing the subjects knowledge. Some of these factors may be high school education, personal curiosity, or possibly discussion of the topic with a family member or other acquaintance. Any of these factors may have allowed a subject to know the difference although he or she did not learn it in a college class.

It was also hypothesized that grade level would influence willingness to have gene therapy. Again, the results did not support that hypothesis (Table 14). Many people replied that their religious beliefs would not allow them to condone gene therapy. The majority of subjects that said they would not have gene therapy, stated that their reason was lack of information on the subject.

Next, it was hypothesized that science majors would be more likely to know the difference between the types of gene therapy. In this case the hypothesis appeared to be supported sufficiently (Table 16). The results observed may have been due to the subjects' education. Science majors are exposed to issues such as gene therapy in their science classes. Therefore, it seemed logical that they would know more about the topic. The data in Table 16 supports this statement.

The final statistical analysis was to determine whether science majors were more willing to have gene therapy done to themselves than non-science majors. The hypothesis was that science majors would be more willing to have gene therapy than non-science majors. In this case the data observed supported the hypothesis (Table 18). Again, this may be due to the education of the subjects. A person that is better acquainted will what

gene therapy entails would probably feel more comfortable with undergoing the procedures. These statements can be supported by the data in Table 18.

Science majors were determined to be more knowledgeable and more willing to have gene therapy (Tables 16, 18). Sciences majors have also had more background in the field of biology. It appears that education is important in understanding a topic such as gene therapy. This is supported in Table 16. The subjects are knowledgeable about the issue and therefore have a basis of information to use to base ethical decisions upon. However, what can less knowledgeable people base an ethical decision on?

Everyday this society is bombarded with commercials on television for work-out equipment, health clubs, vitamins, and various other health care products. People read magazines which discuss topics such as exercise, eating right, and other aspects of personal health. Therefore, it appears that this society is concerned with being healthy. If a person has a treatable genetic disease then they have the opportunity to become more healthy because of treatments such as gene therapy. However, this thesis has shown that the general public (based on student responses) has very limited knowledge of gene therapy. What good is a treatment that no one knows about? This thesis may have shed a little light on the lack of knowledge about a useful therapy that could save lives. People need to be informed about gene therapy. However, there must be people, such as physicians, who must educate their patients about gene therapy. "...it is the moral obligation of the medical profession to make available any technology that can cure or prevent pathology leading to death and disability, in both the present and future generations" (15). Until this is accomplished we cannot truly deal with the ethical issues

that arise from it, and we cannot show the public that there may be hope for those people who could benefit from such a therapy.

Suggestions for Further Research

One idea for further research on this topic is to determine the knowledge and opinions of medical professionals on the topic of gene therapy. As was stated in this thesis, it is important that the public be aware of beneficial treatments such as gene therapy. To obtain information about such procedures, people depend on their doctors to acquaint them with various therapies. However, if physicians are not up to date on current procedures then they cannot tell their patients about those treatments. It may be interesting to determine how much knowledge physicians truly have about the subject of gene therapy. Another suggestion is to discover whether medical students are educated about gene therapy so that they can advise their future patients.

Appendix

Figure 1. "Class Distribution"

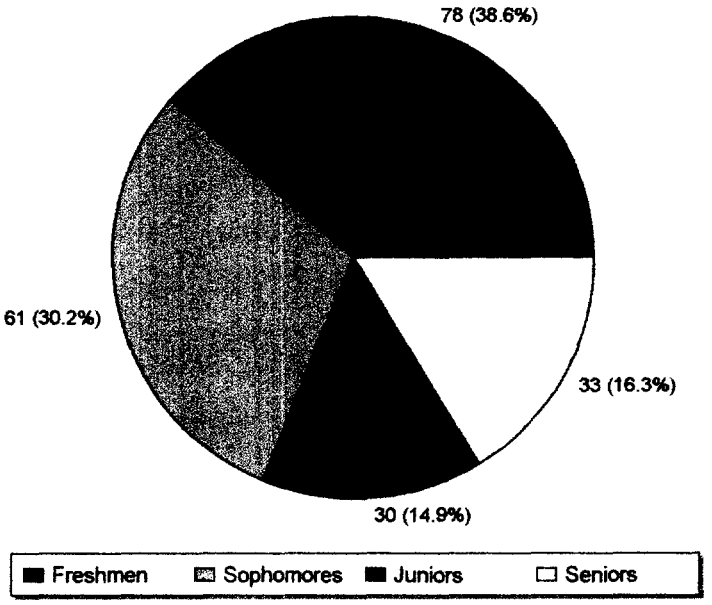
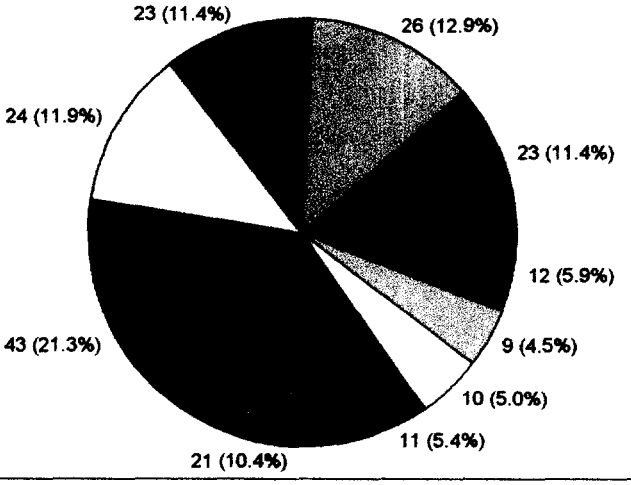


Figure 2. "Major Distribution"



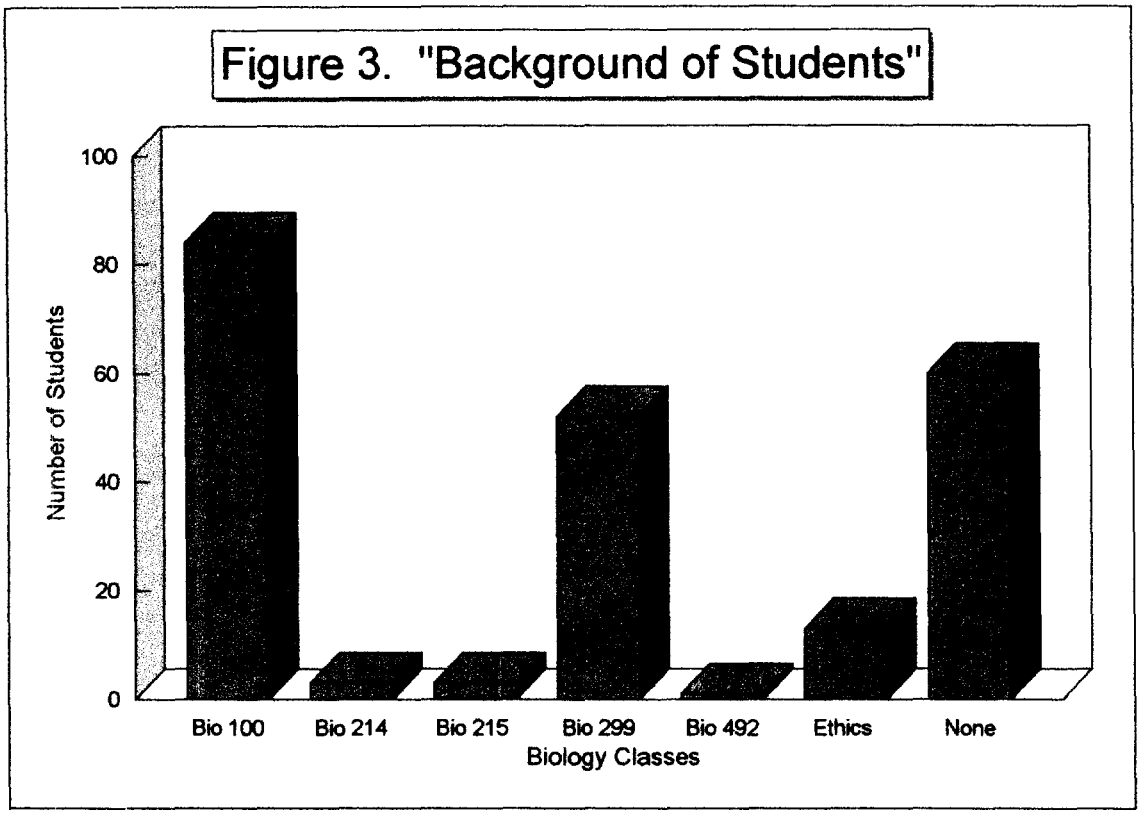


Figure 3. "Background of Students"
100
80
60
40
20
0
Number of Students
Bio 100
Bio 214
Bio 215
Bio 299
Bio 492
Ethics
None
Biology Classes

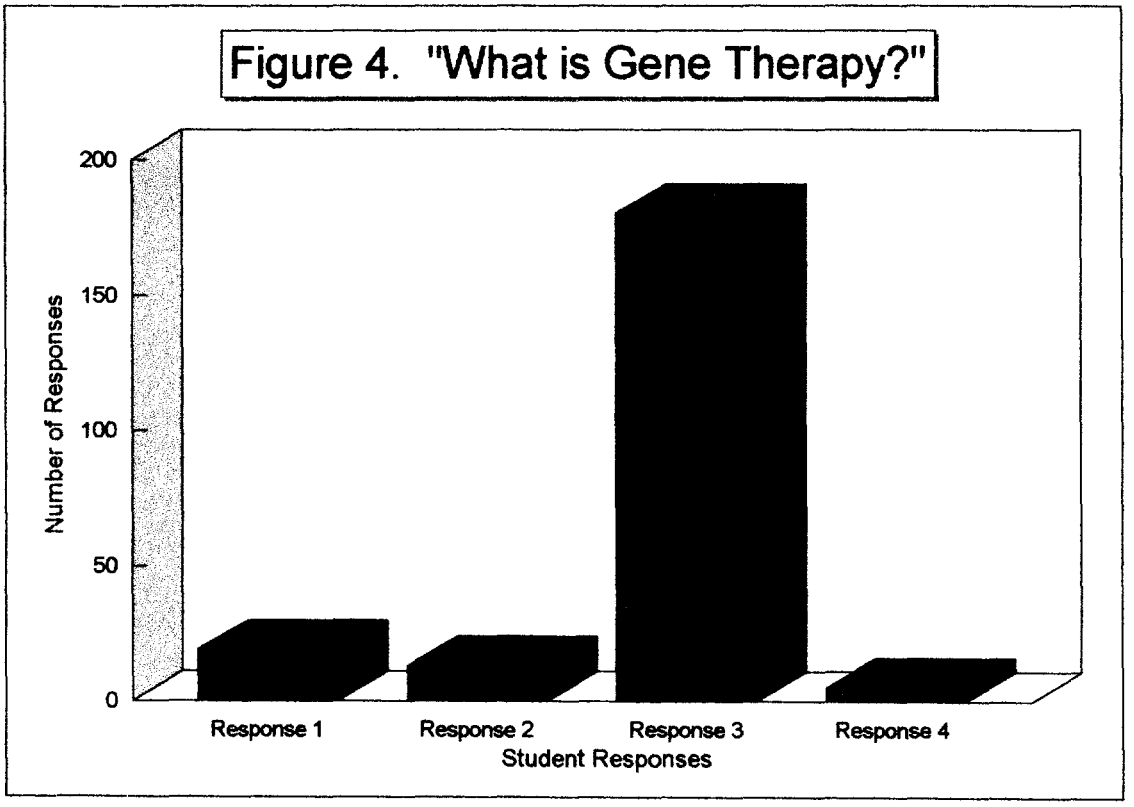


Figure 4. "What is Gene Therapy?"
200
150
100
50
0
Number of Responses
Response 1
Response 2
Response 3
Response 4
Student Responses

Figure 5. "Which Diseases Can be Treated by Gene Therapy?"

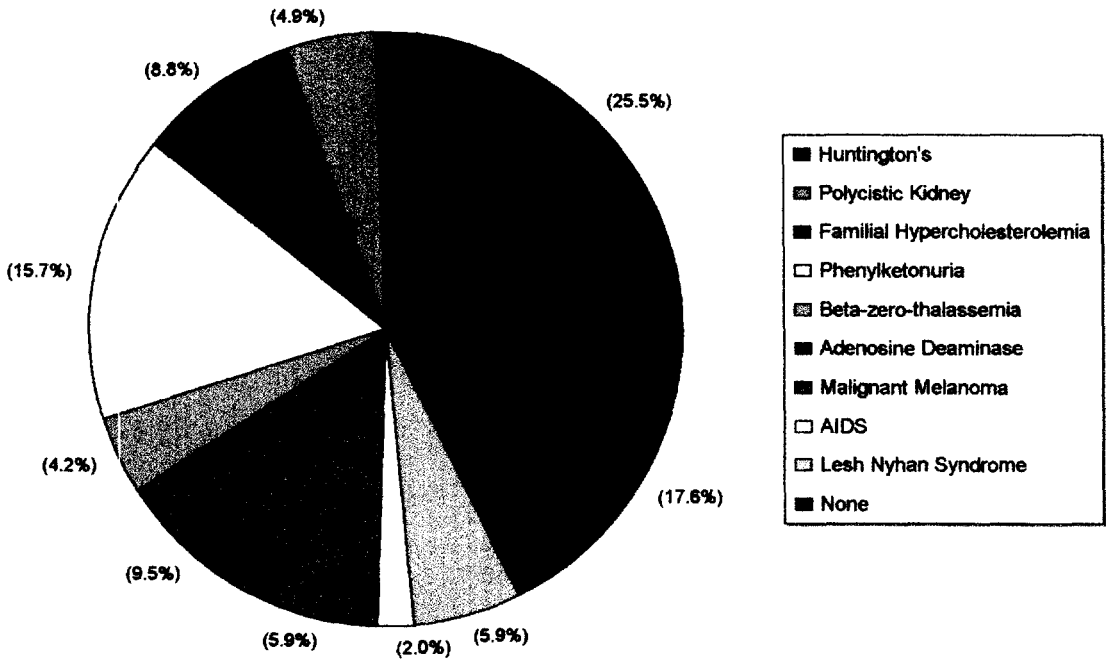


Figure 6. "Student Knowledge of Gene Therapy Types"

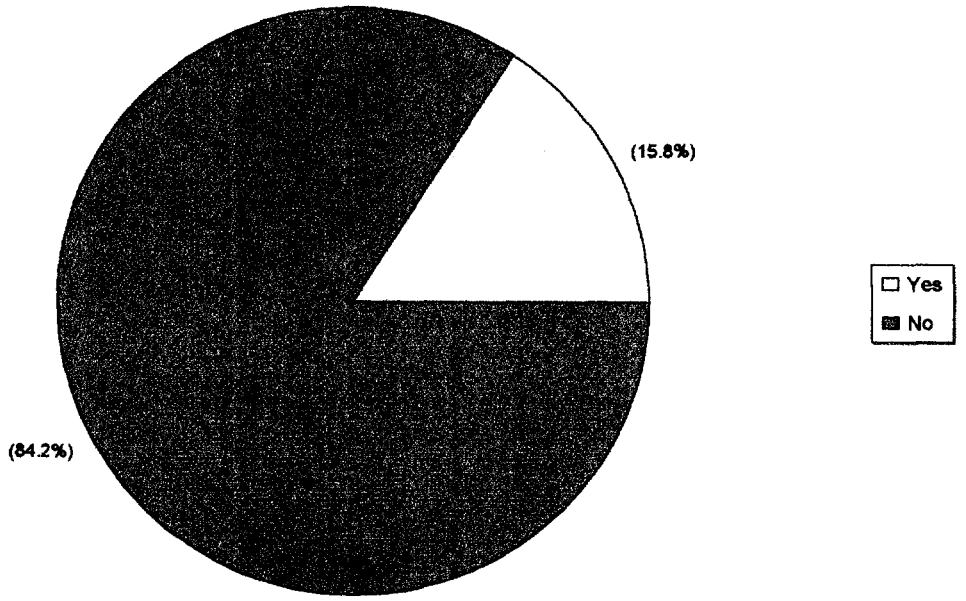


Figure 7. "Ethical Problems With Gene Therapy"

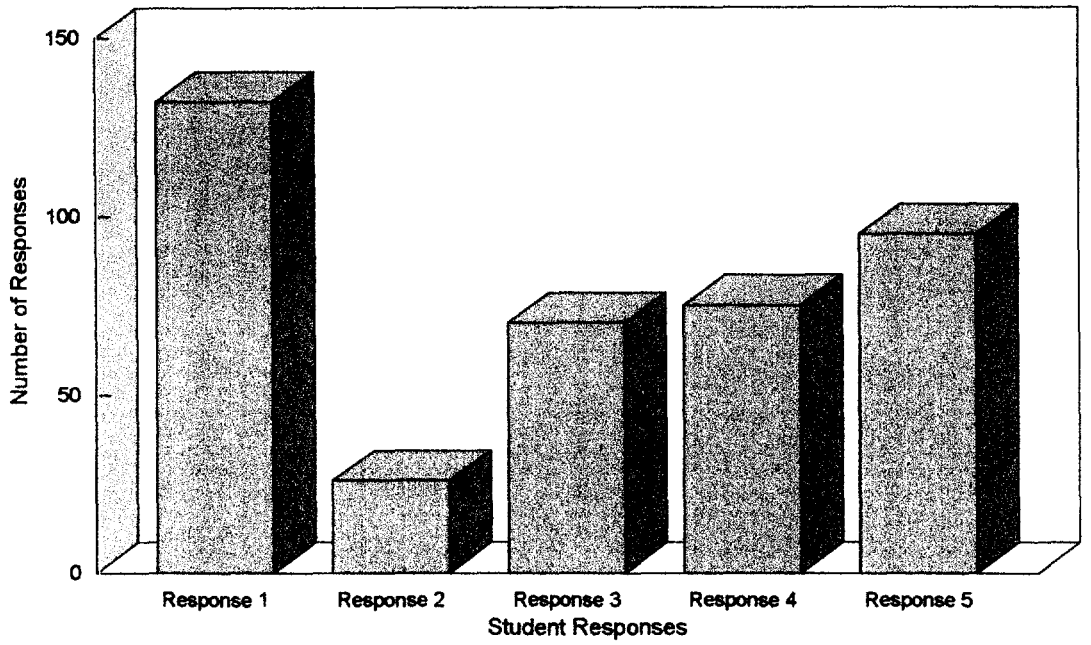


Figure 8. "Would You Have Gene Therapy Done?"

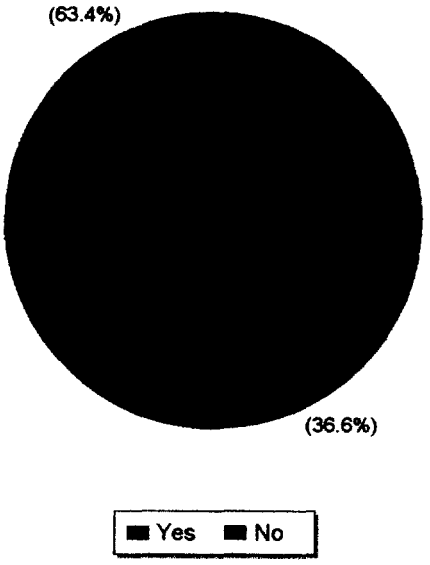


Figure 9. "How Should Gene Therapy be Funded?"

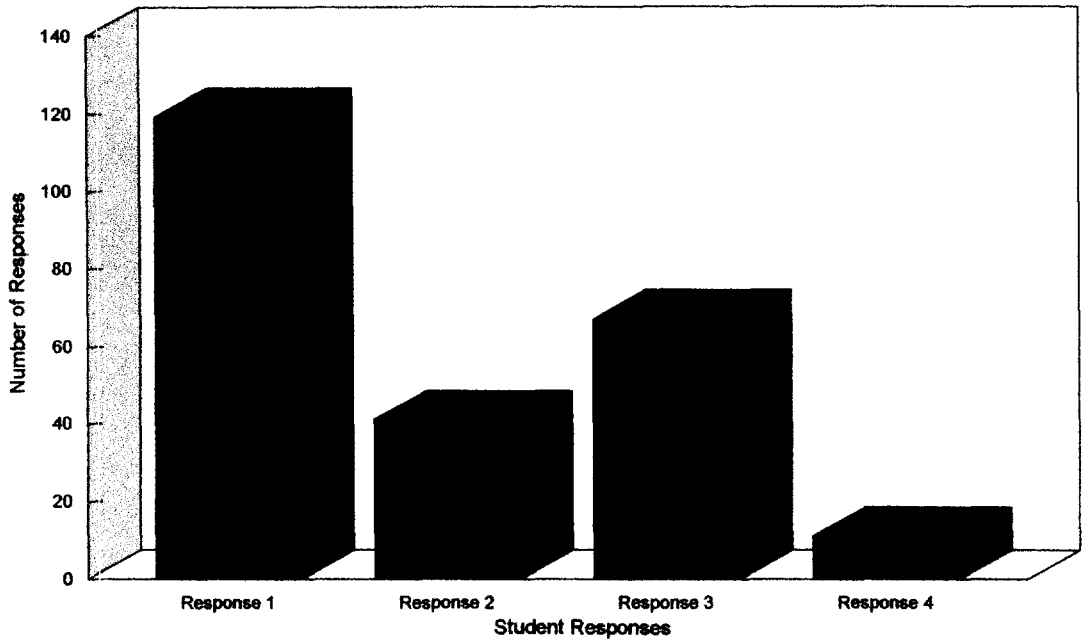
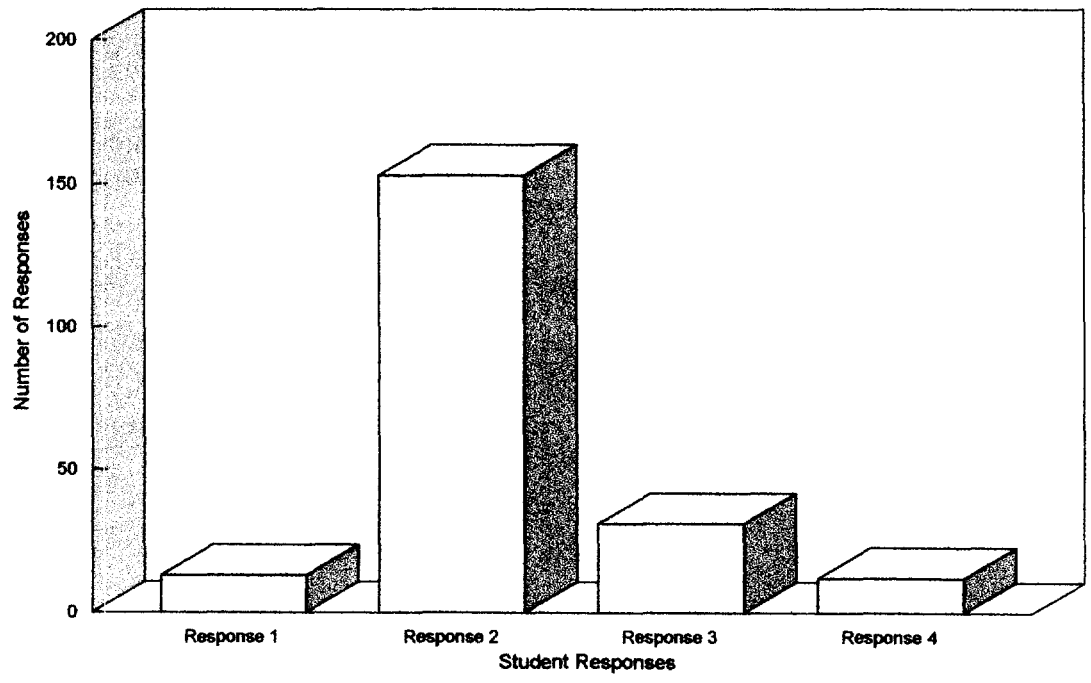


Figure 10. "What Restrictions Should be Placed on Gene Therapy?"



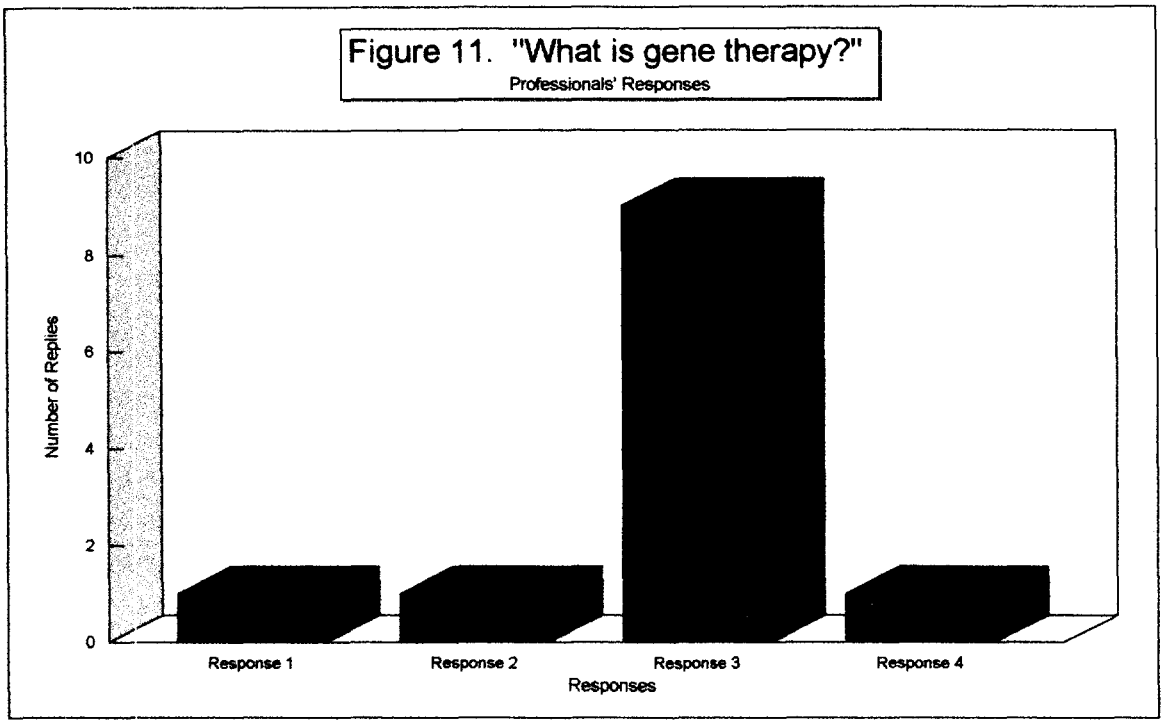


Figure 11. "What is gene therapy?"
Professionals' Responses
Number of Replies
10
8
6
4
2
0
Response 1
Response 2
Response 3
Response 4
Responses

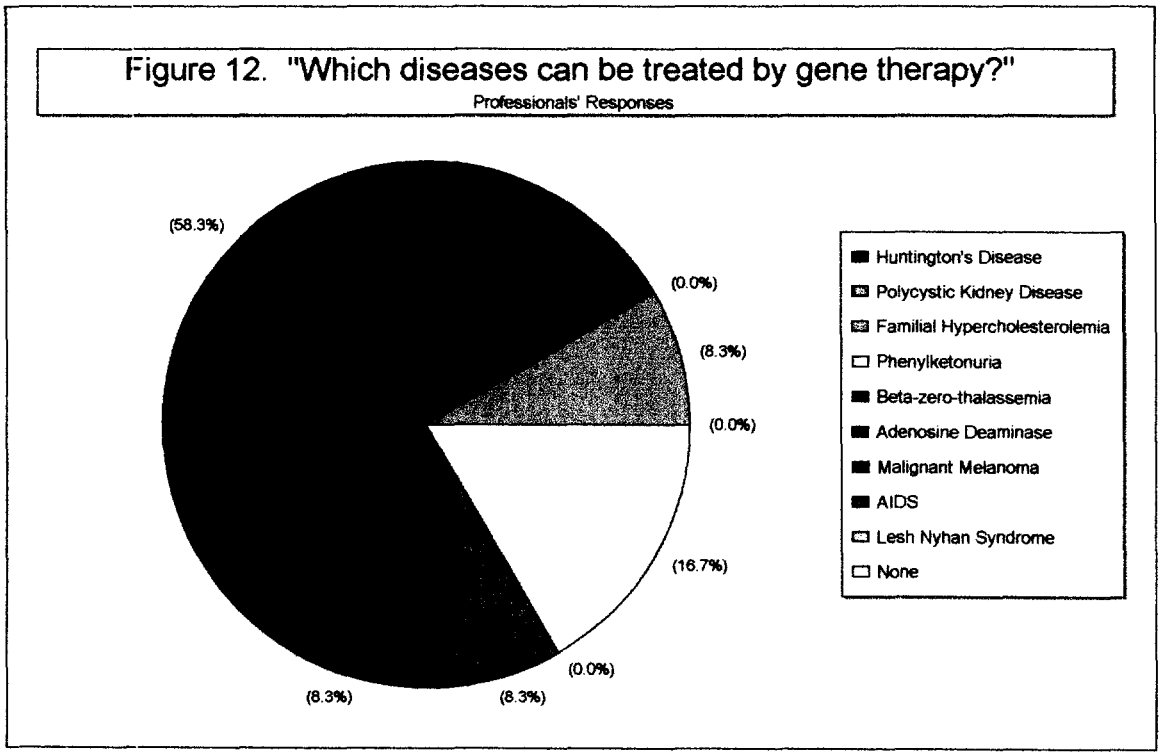


Figure 12. "Which diseases can be treated by gene therapy?"
Professionals' Responses
(58.3%)
(0.0%)
(8.3%)
(0.0%)
(16.7%)
(0.0%)
(8.3%)
(8.3%)
Huntington's Disease
Polycystic Kidney Disease
Familial Hypercholesterolemia
Phenylketonuria
Beta-zero-thalassemia
Adenosine Deaminase
Malignant Melanoma
AIDS
Lesh Nyhan Syndrome
None

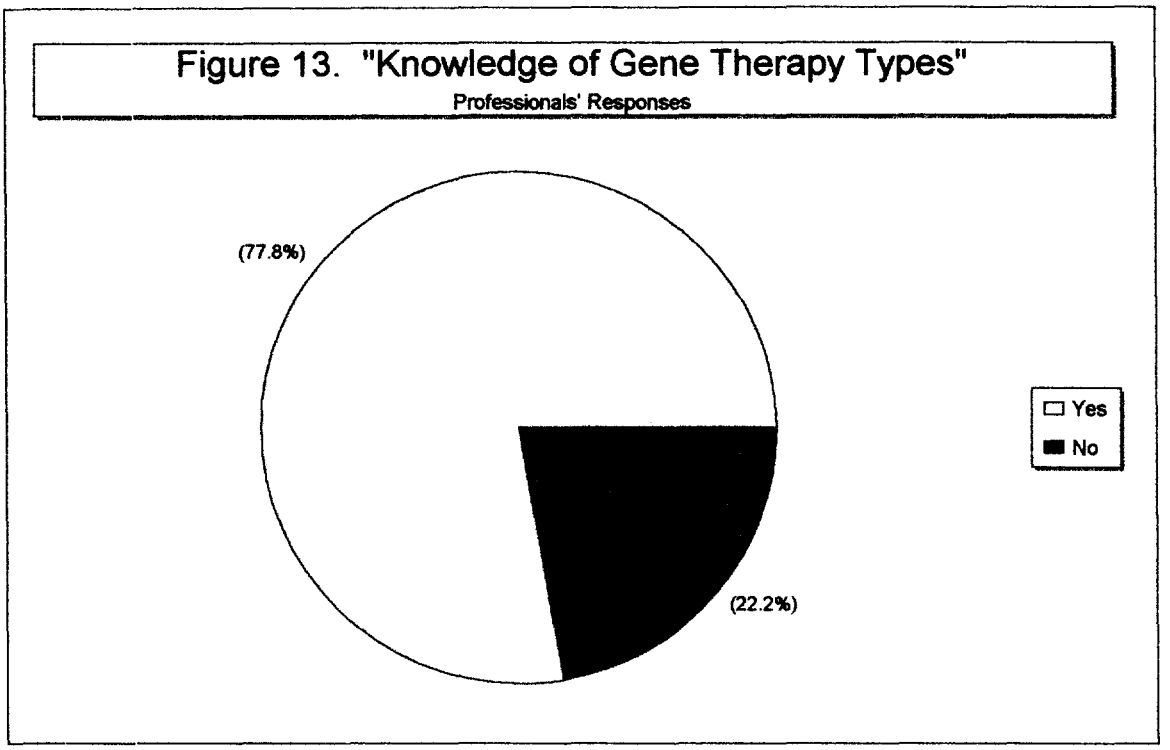


Figure 13. "Knowledge of Gene Therapy Types"
Professionals' Responses
(77.8%)
(22.2%)
Yes
No

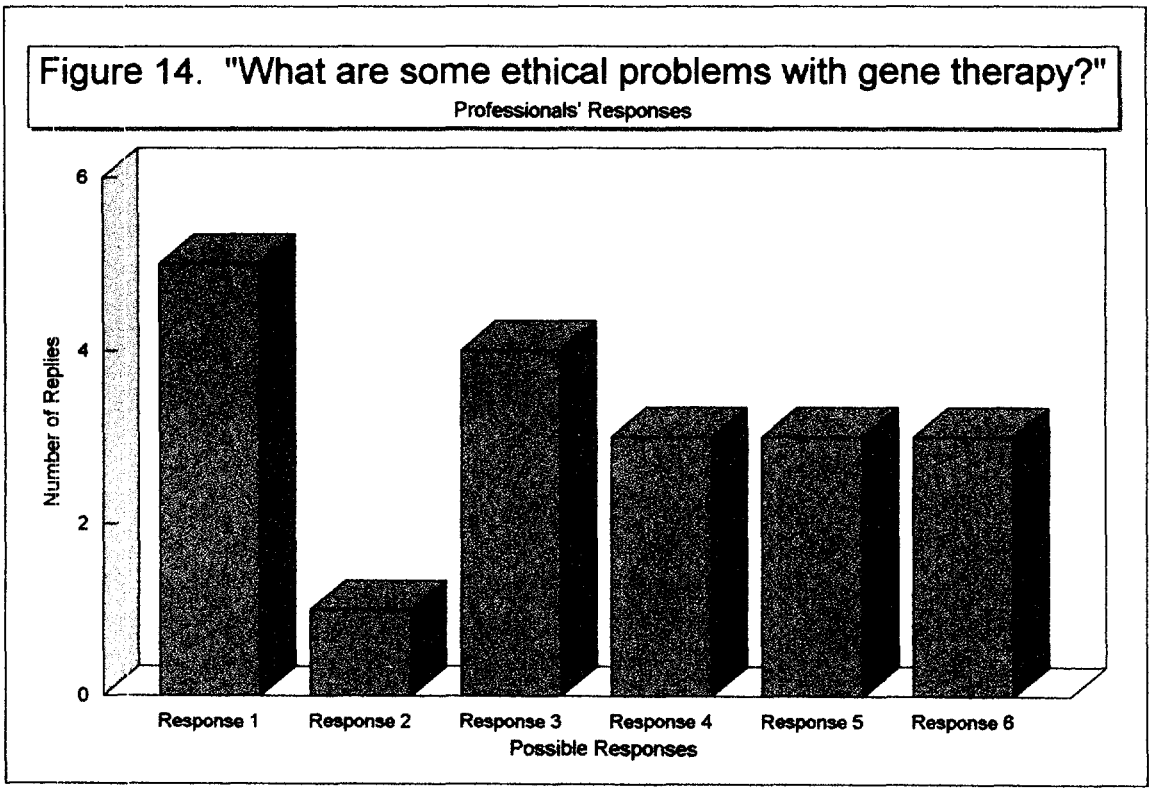


Figure 14. "What are some ethical problems with gene therapy?"
Professionals' Responses
Number of Replies
0
2
4
6
Response 1
Response 2
Response 3
Response 4
Response 5
Response 6
Possible Responses

Figure 15. "Would you have gene therapy done if you had a genetic disease?"
Professionals' Responses.

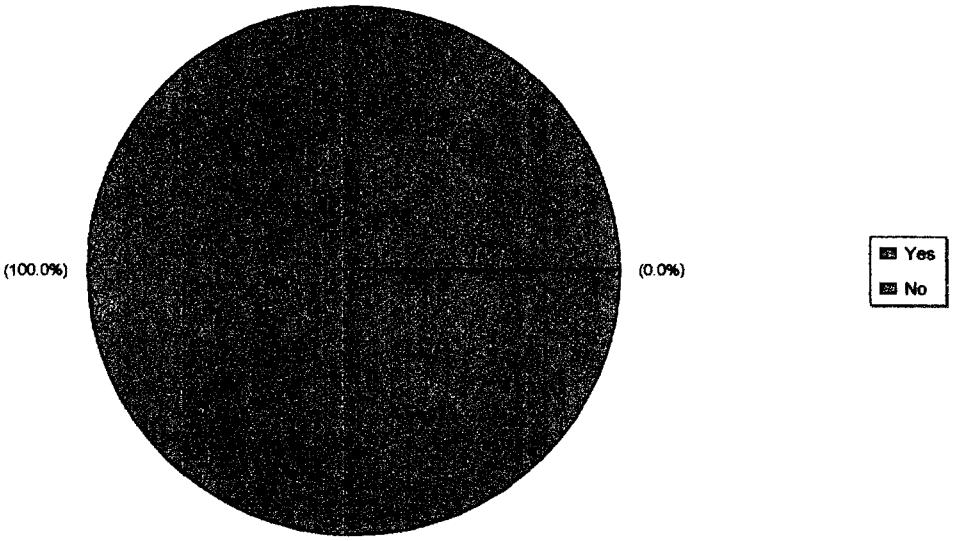


Figure 16. "How do you think gene therapy should be funded?"
Professionals' Responses.

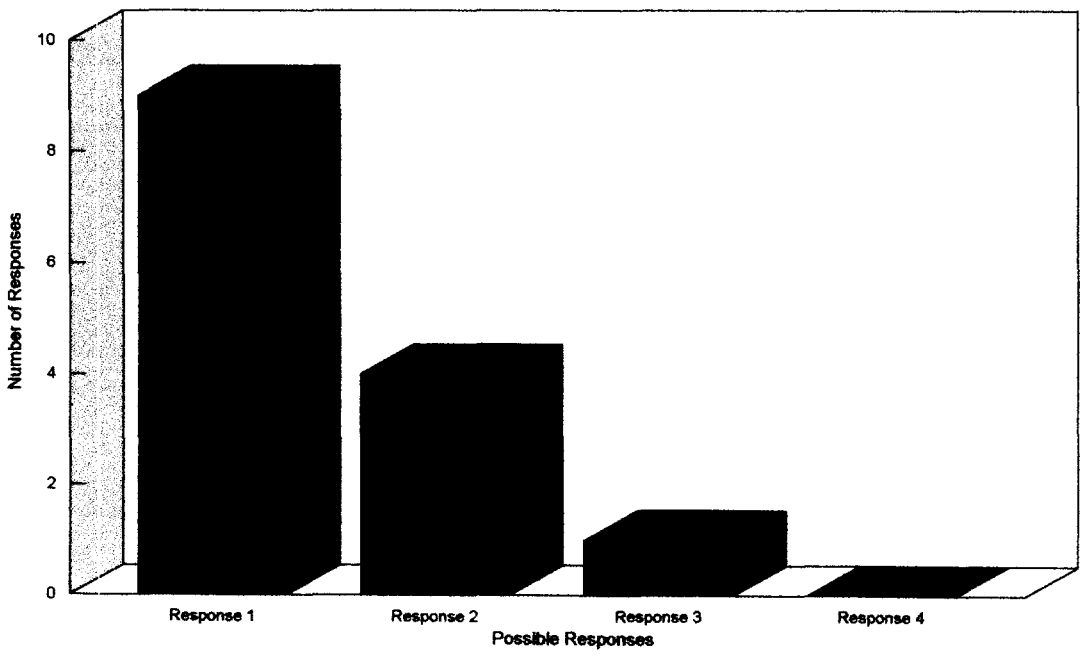
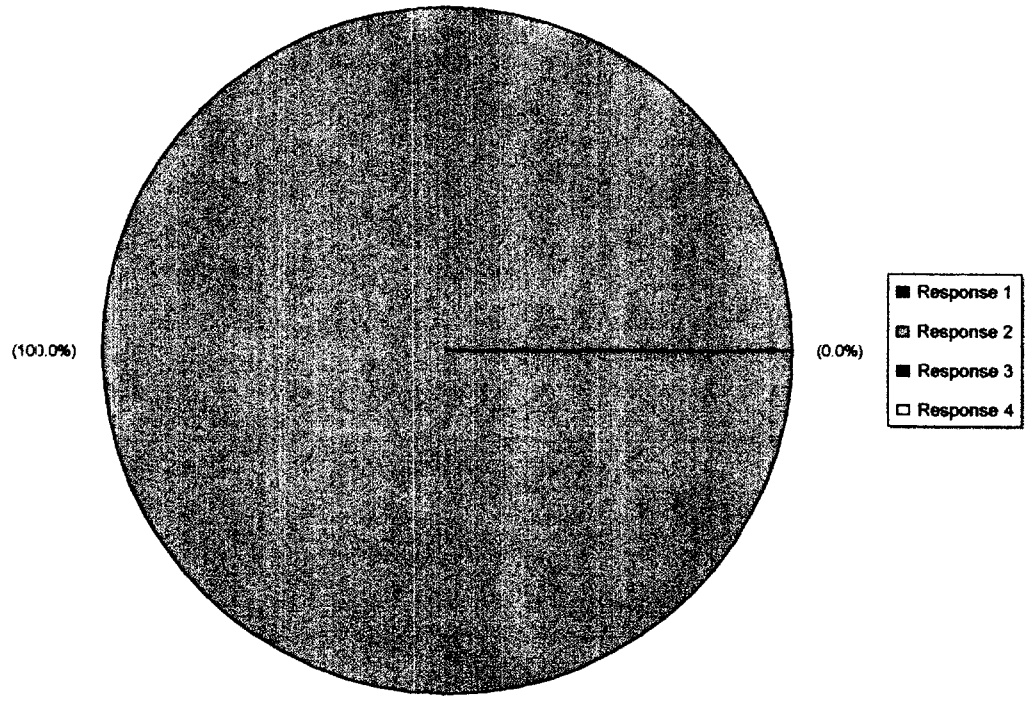


Figure 17. "What kinds of restrictions should we place on gene therapy?"
Professionals' Responses



Gene Therapy Survey

1. Are you a:
   - ☐ Freshman
   - ☐ Sophomore
   - ☐ Junior
   - ☐ Senior
   - ☐ Graduate or Doctoral Student
   - ☐ Professor
   - ☐ Other Profession

2. If you are a student please indicate your major, if you are a professor please indicate your department, or please indicate your profession.

   _____

Only students need to answer question #3.

3. Have you ever taken any of the following classes?
   - ☐ Biology 100
   - ☐ Biology 214
   - ☐ Biology 215
   - ☐ Biology 299
   - ☐ Biology 492
   - ☐ Any ethics classes
   - ☐ None

4. What is gene therapy?
   - ☐ The removal of unwanted DNA sequences from a person's chromosomes.
   - ☐ The cutting of DNA with endonucleases.
   - ☐ Manipulating a person's genes in the attempt to treat a genetic disease.
   - ☐ Inserting the DNA of one species into the genome of a different species.

5. Which disease can be treated by gene therapy?
   - ☐ Huntington's disease
   - ☐ Polycystic kidney disease
   - ☐ Familial Hypercholesterolemia
   - ☐ Phenylketonuria (PKU)
   - ☐ Beta-zero-thalassemia
   - ☐ Adenosine deaminase (ADA)
   - ☐ Malignant melanoma
   - ☐ AIDS
   - ☐ Lesh Nyhan syndrome
   - ☐ None

6. Do you know the difference between somatic cell and sex cell gene therapy?
   - ☐ Yes
   - ☐ No

If yes, please explain.

_____

_____

_____

7. What are some ethical problems with gene therapy?
   - ☐ Some religious beliefs may conflict with gene therapy.
   - ☐ Gene therapy is too time consuming.
   - ☐ Gene therapy costs too much.
   - ☐ There are no laws involving gene therapy procedures.
   - ☐ There may be philosophical beliefs against gene therapy.

8. Would you have gene therapy done on yourself if you had a genetic disease?
   - ☐ Yes
   - ☐ No

Explain:

_____

_____

9. How do you think gene therapy should be funded?
   - ☐ Health insurance
   - ☐ Governmental funding through taxes
   - ☐ The person seeking the therapy should fund it personally
   - ☐ It should not be funded because it should not be done

10. What kinds of restrictions or regulations should we place on gene therapy?
   - ☐ Gene therapy should be available only to people who can afford it.
   - ☐ Gene therapy should only be allowed in medically related cases.
   - ☐ Gene therapy should be available to anyone for any reason.
   - ☐ Gene therapy should not be performed at all.

Thank you for participating in this survey.

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